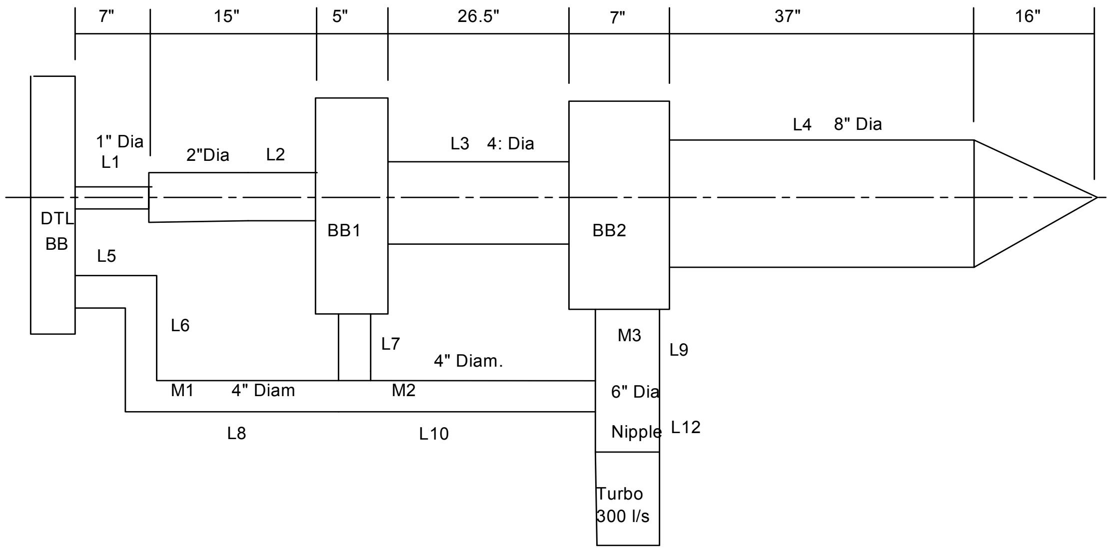


7"
15"
5"
26.5"
7"
37"
16"
L4 8" Dia
1" Dia
L1
2"Dia
L2
L3 4: Dia
DTL
BB
BB1
BB2
L5
L6
L7
4" Diam.
M3
L9
M1
4" Diam
M2
6" Dia
L8
L10
Nipple
L12
Turbo
300 l/s

SPALLATION NEUTRON SOURCE PROJECT OFFICE
LOS ALAMOS NATIONAL LABORATORY

DIAGNOSTIC PLATE VACUUM CALCULATIONS

Purpose of Calculations:
The purpose of this calculation is to determine the required pump size to pump the Diagnostic Plate (D Plate) down to 1.84E-7 torr. To do this calculation required a few

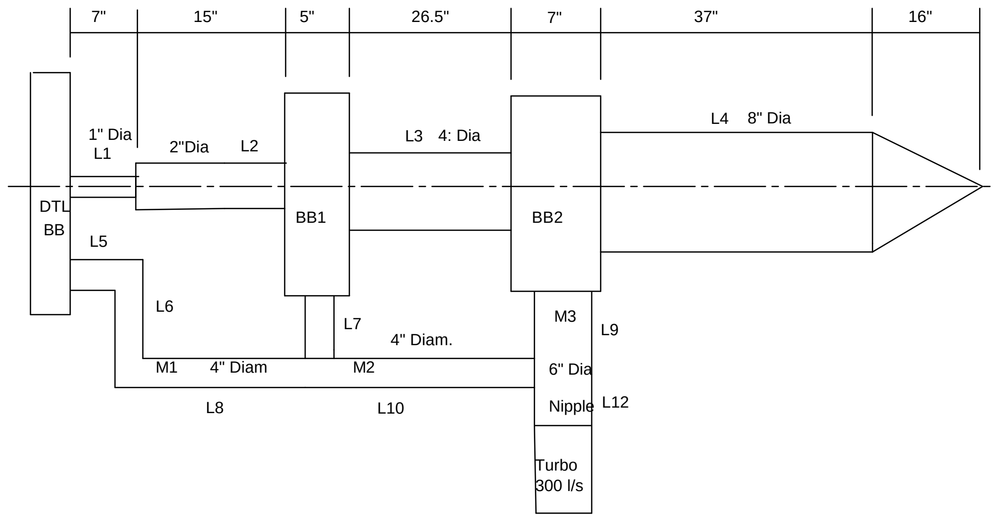
Assumptions:
1. That the Beam Stop would outgas 100 time greater per square centimeter than the rest of the vacuum system. The reason for the increase in outgassing is due to beam heating the surface of the Beam Stop. A page out of a Varian report entitled "Review of Outgas Results" suggests that this is a conservative assumption.
2. All of the hydrogen gas in the beam is absorbed into the beam stop and is not later released into the vacuum system.
3. At the time this calculation was concluded, the outgas rates from the various beam diagnostics equipment had not been calculated. However, Jim O'Hara did do some estimates as to what they would be. Those estimates were used.
4. The area of the valves and bellows are lumped in "Area_Valves". This figure was arrived by correcting the difference between my calculations, which didn't account for any of this, and those done using Uni-graphics. Uni-graphics is the drawing package they use to design and detail the Diagnostic Plate and it is very accurate. This way, the Mathcad calculations match the ones produced by Uni-graphics.
5. Volume calculations were done to get an idea of how long it would take to pump down the system to the transition region, which is the gas region between viscous flow and molecular flow. Beyond that they are not used anywhere else in the calculations.

Results:
The calculated effective pumping speed to the top of the short nipple above the pump (see L12 in the figure) is 180 liters/sec. The size of the vacuum pump that is required to meet this pumping speed is 242 liters/sec. If a 300 liter/sec pump is used in the system, and that is what is planned on being used, then this should provide enough pumping to meet the needs of the D Plate vacuum system.

Robert Gillis
TechSource
September 18, 2001

Diagnostic Plate

The goal of this calculation is to size the required vacuum pump need to pump this system down.



Inputs

$outgas\_ss := 1 \cdot 10^{-10} \; \frac{(torr - liters)}{sec - cm^2}$

This is the steady state outgas rate of the stainless steel system.

$outgas_{beam\_stop} := 1 \cdot 10^{-8} \; \frac{(torr - liters)}{sec - cm^2}$

This is a conservative guess of the outgas rate of the nickel beam stop during the time the beam is hitting it. I am assuming it is 100 times greater than the outgas rate for SS at steady state conditions. See attach report by Varian.

$bb1Len := 11.43 \quad bb1Diam := 24.13$

$bb2Len := 16.5 \quad bb2Diam := 24.13$

Beam Box dimensions in cm

$Area\_valves := 2502 \quad cm^2$

This also includes all bellows areas.

$Q\_valve := Area\_valves \cdot outgas\_ss \quad \frac{torr \cdot liters}{sec}$

$M_{ave} := 28.98 \quad \frac{g}{gram \cdot mole}$

The average mass of the gas (air) in the beam line

$Max\_allow\_pressure := 1.84 \cdot 10^{-7} \quad Torr$

$T := 296$ temperature in degrees K

The pipe lengths in inches are: **The pipe lengths in cm are:**

L1_in := 7	L1_cm := L1_in·2.54	L1_cm = 17.78
L2_in := 15	L2_cm := L2_in·2.54	L2_cm = 38.1
L3_in := 26.5	L3_cm := L3_in·2.54	L3_cm = 67.31
L4_in := 37	L4_cm := L4_in·2.54	L4_cm = 93.98
L5_in := 9	L5_cm := L5_in·2.54	L5_cm = 22.86
L6_in := 5	L6_cm := L6_in·2.54	L6_cm = 12.7
L7_in := 4	L7_cm := L7_in·2.54	L7_cm = 10.16
L8_in := 16	L8_cm := L8_in·2.54	L8_cm = 40.64
L9_in := 4	L9_cm := L9_in·2.54	L9_cm = 10.16
L10_in := 32	L10_cm := L10_in·2.54	L10_cm = 81.28
L12_in := 14	L12_cm := L12_in·2.54	L12_cm = 35.56

The pipe diameters in inches are: **Pipe diameters in cm are:**

D1_in := 0.875	D1_cm := D1_in·2.54	D1_cm = 2.223
D2_in := 1.875	D2_cm := D2_in·2.54	D2_cm = 4.763
D3_in := 3.87	D3_cm := D3_in·2.54	D3_cm = 9.83
D4_in := 7.87	D4_cm := D4_in·2.54	D4_cm = 19.99
D5_in := 3.875	D5_cm := D5_in·2.54	D5_cm = 9.842
D6_in := 3.875	D6_cm := D6_in·2.54	D6_cm = 9.842
D7_in := 3.875	D7_cm := D7_in·2.54	D7_cm = 9.842
D8_in := 3.875	D8_cm := D8_in·2.54	D8_cm = 9.842
D9_in := 5.76	D9_cm := D9_in·2.54	D9_cm = 14.63
D10_in := 3.875	D10_cm := D10_in·2.54	D10_cm = 9.842
D12_in := 5.76	D12_cm := D12_in·2.54	D12_cm = 14.63

Volume and area calculations

$$Vol_{DTL\_BB} := \pi\cdot\left[\frac{(18\cdot 2.54)^2}{4}\right]\cdot 4.3\cdot 2.54\ \ldots$$
$$+\left[3(4.5\cdot 2)\,4+\frac{\pi\left(1.25^2\right)}{4}3\right]\cdot 16.387064$$

.39 is a conversion to cm^3

$$Vol_{DTL\_BB} = 1.976\times 10^4$$

Did not account for bellows added volume which is small..

$$Area_{DTL\_BB} := 2\cdot\frac{\pi\cdot(18\cdot 2.54)^2}{4}+\left[\pi\cdot(18\cdot 2.54)\right]\cdot 8\cdot 2.54+\left[3\cdot(4.5+2)\cdot 2\cdot 4+\pi\cdot 2.5\cdot 3\right]\cdot 6.451$$

6.45 is a conversion to cm^2

$$Area_{DTL\_BB} = 7.361\times 10^3$$

Did account for bellows added area

$$Vol\_D1_{cm} := \pi\cdot\left(\frac{D1\_cm^2}{4}\right)\cdot L1\_cm \qquad Vol\_D1_{cm} = 68.977$$

$$Area\_D1_{cm} := \pi\cdot(D1\_cm)\cdot L1\_cm \qquad Area\_D1_{cm} = 124.143$$

$$Vol\_D2_{cm} := \pi\cdot\left(\frac{D2\_cm^2}{4}\right)\cdot L2\_cm \qquad Vol\_D2_{cm} = 678.711$$

$$Area\_D2_{cm} := \pi\cdot(D2\_cm)\cdot L2\_cm \qquad Area\_D2_{cm} = 570.046$$

$$Vol\_D3_{cm} := \pi\cdot\left(\frac{D3\_cm^2}{4}\right)\cdot L3\_cm \qquad Vol\_D3_{cm} = 5.108\times 10^3$$

$$Area\_D3_{cm} := \pi\cdot(D3\_cm)\cdot L3\_cm \qquad Area\_D3_{cm} = 2.079\times 10^3$$

$$Vol\_D4_{cm} := \pi\cdot\left(\frac{D4\_cm^2}{4}\right)\cdot L4\_cm \qquad Vol\_D4_{cm} = 2.949\times 10^4$$

$Area\_D4_{cm} := \pi \cdot (D4\_cm) \cdot L4\_cm$ $\qquad Area\_D4_{cm} = 5.902 \times 10^{3}$

$Vol\_D5_{cm} := \pi \cdot \left(\frac{D5\_cm^{2}}{4}\right) \cdot L5\_cm$ $\qquad Vol\_D5_{cm} = 1.739 \times 10^{3}$

$Area\_D5_{cm} := \pi \cdot (D5\_cm) \cdot L5\_cm$ $\qquad Area\_D5_{cm} = 706.857$

$Vol\_D6_{cm} := \pi \cdot \left(\frac{D6\_cm^{2}}{4}\right) \cdot L6\_cm$ $\qquad Vol\_D6_{cm} = 966.283$

$Area\_D6_{cm} := \pi \cdot (D6\_cm) \cdot L6\_cm$ $\qquad Area\_D6_{cm} = 392.698$

$Vol\_D7_{cm} := \pi \cdot \left(\frac{D7\_cm^{2}}{4}\right) \cdot L7\_cm$ $\qquad Vol\_D7_{cm} = 773.027$

$Area\_D7_{cm} := \pi \cdot (D7\_cm) \cdot L7\_cm$ $\qquad Area\_D7_{cm} = 314.159$

$Vol\_D8_{cm} := \pi \cdot \left(\frac{D8\_cm^{2}}{4}\right) \cdot L8\_cm$ $\qquad Vol\_D8_{cm} = 3.092 \times 10^{3}$

$Area\_D8_{cm} := \pi \cdot (D8\_cm) \cdot L8\_cm$ $\qquad Area\_D8_{cm} = 1.257 \times 10^{3}$

$Vol\_D9_{cm} := \pi \cdot \left(\frac{D9\_cm^{2}}{4}\right) \cdot L9\_cm$ $\qquad Vol\_D9_{cm} = 1.708 \times 10^{3}$

$Area\_D9_{cm} := \pi \cdot (D9\_cm) \cdot L9\_cm$ $\qquad Area\_D9_{cm} = 466.982$

$Vol\_D10_{cm} := \pi \cdot \left(\frac{D10\_cm^{2}}{4}\right) \cdot L10\_cm$ $\qquad Vol\_D10_{cm} = 6.184 \times 10^{3}$

$Area\_D10_{cm} := \pi \cdot (D10\_cm) \cdot L10\_cm$ $\qquad Area\_D10_{cm} = 2.513 \times 10^{3}$

$Vol\_D12_{cm} := \pi \cdot \left(\frac{D12\_cm^{2}}{4}\right) \cdot L10\_cm$ $\qquad Vol\_D12_{cm} = 1.366 \times 10^{4}$

$Area\_D12_{cm} := \pi \cdot (D12\_cm) \cdot L10\_cm$ $\qquad Area\_D12_{cm} = 3.736 \times 10^{3}$

$$Vol\_Beam\_Stop_{cm} := \frac{\pi}{3}\left(\frac{7.87\cdot 2.54}{2}\right)^{2} 17\cdot 2.54$$

$$Vol\_Beam\_Stop_{cm} = 4.517\times 10^{3}$$

$$Area\_Beam\_Stop_{cm} := \pi 10(10 + 44.45)$$ Converted inches to cm by hand

$$Area\_Beam\_Stop_{cm} = 1.711\times 10^{3}$$

$$Q_{beam\_stop} := Area\_Beam\_Stop_{cm}\cdot outgas_{beam\_stop} \qquad Q_{beam\_stop} = 1.711\times 10^{-5}$$

$$Vol\_bb1 := \frac{\left(\pi\cdot bb1Diam^{2}\right)}{4}\cdot bb1Len + \frac{3\cdot\left[\pi\cdot(3\cdot 2.54)^{2}\right]}{4}\cdot 7.5\cdot 2.54 + \frac{\left[\pi\cdot(3\cdot 2.54)^{2}\right]}{4}\cdot 4.5\cdot 2.54 \;... + \frac{3\cdot\left[\pi\cdot(1.5\cdot 2.54)^{2}\right]}{4}\cdot 2.5\cdot 2.54$$

$$Vol\_bb1 = 8.572\times 10^{3}$$

$$Area\_bb1_{cm} := (\pi\cdot bb1Diam)\cdot bb1Len + 3\cdot\left[\pi\cdot(3\cdot 2.54)\right]\cdot 7.5\cdot 2.54 + \left[\pi\cdot(3\cdot 2.54)\right]\cdot 4.5\cdot 2.54 \;... + 3\cdot\left[\pi\cdot(1.5\cdot 2.54)\right]\cdot 2.5\cdot 2.54$$

$$Area\_bb1_{cm} = 2.736\times 10^{3}$$

$$Vol\_bb2 := \frac{\left(\pi\cdot bb2Diam^{2}\right)}{4}\cdot bb2Len + \frac{\left[\pi\cdot(6\cdot 2.54)^{2}\right]}{4}\cdot 6.5\cdot 2.54 + 2\cdot\left[\frac{\left[\pi\cdot(4\cdot 2.54)^{2}\right]}{4}\cdot 7.5\cdot 2.54\right]$$

$$Vol\_bb2 = 1.365\times 10^{4}$$

$$Area\_bb2_{cm} := (\pi\cdot bb2Diam)\cdot bb2Len + \left[\pi\cdot(6\cdot 2.54)\right]\cdot 6.5\cdot 2.54 + 2\cdot\left[\left[\pi\cdot(4\cdot 2.54)\right]\cdot 7.5\cdot 2.54\right]$$

$$Area\_bb2_{cm} = 3.257\times 10^{3}$$

$$Total\_Vol_{cm} := Vol_{DTL\_BB} + Vol\_D1_{cm} + Vol\_D2_{cm} + Vol\_D3_{cm} + Vol\_D4_{cm} \;... + Vol\_D5_{cm} + Vol\_D6_{cm} + Vol\_D7_{cm} + Vol\_D8_{cm} + Vol\_D9_{cm} + Vol\_D10_{cm} \;... + Vol\_D12_{cm} + Vol\_Beam\_Stop_{cm} + Vol\_bb1 + Vol\_bb2$$

$$Total\_Vol_{cm} = 1.1\times 10^{5}$$

$$Total\_Area_{cm} := Area_{DTL\_BB} + Area\_D1_{cm} + Area\_D2_{cm} + Area\_D3_{cm} + Area\_D4_{cm} \ldots + Area\_D5_{cm} + Area\_D6_{cm} + Area\_D7_{cm} + Area\_D8_{cm} + Area\_D9_{cm} \ldots + Area\_D10_{cm} + Area\_D12_{cm} + Area\_bb1_{cm} + Area\_bb2_{cm} + Area\_valves \ldots + Area\_Beam\_Stop_{cm}$$

$$Total\_Area_{cm} = 3.563 \times 10^{4}$$

Calculate the outgas rates in torr-liters/sec.

$Q1 := \pi \cdot D1\_cm \cdot L1\_cm \cdot outgas\_ss$ $\quad Q1 = 1.241 \times 10^{-8}$

$Q2 := \pi \cdot D2\_cm \cdot L2\_cm \cdot outgas\_ss$ $\quad Q2 = 5.7 \times 10^{-8}$

$Q3 := \pi \cdot D3\_cm \cdot L3\_cm \cdot outgas\_ss$ $\quad Q3 = 2.079 \times 10^{-7}$

$Q4 := \pi \cdot D4\_cm \cdot L4\_cm \cdot outgas\_ss$ $\quad Q4 = 5.902 \times 10^{-7}$

$Q5 := \pi \cdot D5\_cm \cdot L5\_cm \cdot outgas\_ss$ $\quad Q5 = 7.069 \times 10^{-8}$

$Q6 := \pi \cdot D6\_cm \cdot L6\_cm \cdot outgas\_ss$ $\quad Q6 = 3.927 \times 10^{-8}$

$Q7 := \pi \cdot D7\_cm \cdot L7\_cm \cdot outgas\_ss$ $\quad Q7 = 3.142 \times 10^{-8}$

$Q8 := \pi \cdot D8\_cm \cdot L8\_cm \cdot outgas\_ss$ $\quad Q8 = 1.257 \times 10^{-7}$

$Q9 := \pi \cdot D9\_cm \cdot L9\_cm \cdot outgas\_ss$ $\quad Q9 = 4.67 \times 10^{-8}$

$Q10 := \pi \cdot D10\_cm \cdot L10\_cm \cdot outgas\_ss$ $\quad Q10 = 2.513 \times 10^{-7}$

$Q12 := \pi \cdot D12\_cm \cdot L12\_cm \cdot outgas\_ss$ $\quad Q12 = 1.634 \times 10^{-7}$

Calculate the outgas rates from the stainless steel beam boxes in torr*liters/sec:

$Qbb1 := Area\_bb1_{cm} \cdot outgas\_ss$ $\quad Qbb1 = 2.736 \times 10^{-7}$

$Qbb2 := Area\_bb2_{cm} \cdot outgas\_ss$ $\quad Qbb2 = 3.257 \times 10^{-7}$

The outgas loads, in torr*liters/sec, from the diagnostic equipment has been calculated by Jim O'Hara.

$$Qws := 1.7 \cdot 10^{-7}$$

$$Qfaraday := 1.8 \cdot 10^{-7}$$

$$Qharp := 2.1 \cdot 10^{-7}$$

$$Qbpm := 4.1 \cdot 10^{-7}$$

Calculate the outgas rate in, torr*liters/sec*cm^2, of the DTL diagnostic box at the end of the DTL tanks. (Box only, not any of the diagnostic equipment.)

The outgas from the beam box is:

$$Q\_DTL\_b\_box := Area_{DTL\_BB} \cdot outgas\_ss$$

$$Q\_DTL\_b\_box = 7.361 \times 10^{-7} \quad \frac{torr \cdot liters}{sec}$$

Determine the total outgas load of the system. Assume that each beam box has 3 diagnostic units (faraday cups) in it including the DTL diagnostic box.

$$\begin{aligned} Q\_total := {} & Q1 + Q\_valve + Q2 + Q3 + Q4 + Q5 + Q6 + Q7 + Q8 + Q9 \ldots \\ & + Q10 + Q12 + Qbb1 + Qbb2 \ldots \\ & + 8 \cdot Qbpm + Q\_DTL\_b\_box + Q_{beam\_stop} \end{aligned}$$

$$Q\_total = 2.357 \times 10^{-5} \quad torr \cdot \frac{liters}{sec}$$

Calculate the conductance's for the various pipes.

The average mass of the gas in the beam line is

$$M_{ave} := 28 \quad \frac{g}{g \cdot mole}$$

The conductance's, in liters/sec, for each of the tubes are: (See Roth, page 87, equation 3.108)

$$con1 := 3.81 \left(\frac{T}{M_{ave}}\right)^{\frac{1}{2}} \left(\frac{D1\_cm^3}{L1\_cm + 1.33 D1\_cm}\right) \qquad con1 = 6.558$$

$$con2 := 3.81\left(\frac{T}{M_{ave}}\right)^{\frac{1}{2}}\left(\frac{D2\_cm^3}{L2\_cm + 1.33\cdot D2\_cm}\right)$$ $con2 = 30.115$

$$con3 := 3.81\left(\frac{T}{M_{ave}}\right)^{\frac{1}{2}}\left(\frac{D3\_cm^3}{L3\_cm + 1.33\cdot D3\_cm}\right)$$ $con3 = 146.372$

$$con4 := 3.81\left(\frac{T}{M_{ave}}\right)^{\frac{1}{2}}\left(\frac{D4\_cm^3}{L4\_cm + 1.33\cdot D4\_cm}\right)$$ $con4 = 820.712$

(Con5 & con6) Calculate the conductance, in liters/sec, of the double elbow near the DTL tank

$L_{ax} := L5\_cm + L6\_cm$

For these equations, see Roth, pages 90, equation 3.127

$$C_{dbl\_elbow} := 3.81\cdot\frac{\dfrac{\left(\frac{T}{M_{ave}}\right)^{\frac{1}{2}}\cdot D5\_cm^3}{L_{ax}+1.33\cdot D5\_cm}}{2}$$

I divided the conductance of the elbow by 2 because it is a double elbow.

$C_{dbl\_elbow} = 121.392$

$$con7 := 3.81\left(\frac{T}{M_{ave}}\right)^{\frac{1}{2}}\left(\frac{D7\_cm^3}{L7\_cm + 1.33\cdot D7\_cm}\right)$$ $con7 = 508.014$

$$con8 := 3.81\left(\frac{T}{M_{ave}}\right)^{\frac{1}{2}}\left(\frac{D8\_cm^3}{L8\_cm + 1.33\cdot D8\_cm}\right)$$ $con8 = 219.83$

$$con9 := 3.81\left(\frac{T}{M_{ave}}\right)^{\frac{1}{2}}\left(\frac{D9\_cm^3}{L9\_cm + 1.33\cdot D9\_cm}\right)$$ $con9 = 1.31 \times 10^3$

$$con10 := 3.81\left(\frac{T}{M_{ave}}\right)^{\frac{1}{2}}\left(\frac{D10\_cm^3}{L10\_cm + 1.33\cdot D10\_cm}\right)$$ $con10 = 125.162$

$$con12 := 3.81\left(\frac{T}{M_{ave}}\right)^{\frac{1}{2}}\left(\frac{D12\_cm^3}{L12\_cm + 1.33 \cdot D12\_cm}\right) \qquad con12 = 705.102$$

Calculate the gas loads as they flow toward the pump

The outgas load (q) flowing out of the DTL Beam Box through the two elbows is:

$$flow\_manifold_1 := Q\_DTL\_b\_box + Q5 + Q6 + 3 \cdot Qfaraday + \frac{Q1}{2} + Q8$$

$$flow\_manifold_1 = 1.518 \times 10^{-6} \ \frac{(torr \cdot liters)}{sec}$$

The outgas load (q) flowing from the 1st Beam Box toward the pump.

$$flow\_manifold_2 := flow\_manifold_1 + \frac{Q1}{2} + Q\_valve + Qbb1 + Q2 + 3 \cdot Qfaraday + Q7 + Q10$$

$$flow\_manifold_2 = 2.928 \times 10^{-6} \ \frac{(torr \cdot liters)}{sec}$$

The outgas load (q) flowing out of the 2nd Beam Box toward the pump.

$$flow\_manifold_3 := Q3 + Qbb2 + 3 \cdot Qfaraday + Q4 + Q9 + Q_{beam\_stop}$$

$$flow\_manifold_3 = 1.882 \times 10^{-5} \ \frac{(torr \cdot liters)}{sec}$$

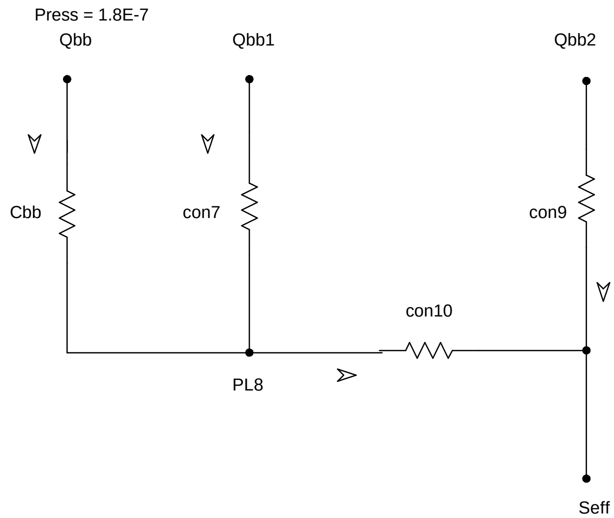
The outgas total gas load going down the nipple to the pump is:

$$Q\_nipple := flow\_manifold_2 + flow\_manifold_3 + Q12$$

$$Q\_nipple = 2.191 \times 10^{-5} \ \frac{(torr \cdot liters)}{sec}$$

Determine the required Effective pumping speed needed to pump the vacuum system down

The nodal network for solving the following 5 equations that will determine the effective pumping speed (Seff) is giving below. Since the vacuum pressure is known at the top left corner, the 5 equations can be solved without resorting to matrix algebra.



$$C_1 := \frac{1}{C_{dbl\_elbow}} + \frac{1}{con8}$$

$$C_{bb} := \frac{1}{C_1}$$

$$C_{bb} = 78.206 \ \ torr \cdot \frac{liters}{sec}$$

$$Q_{bb} := flow\_manifold_1$$

$$Q_{bb1} := flow\_manifold_2$$

$$Q_{bb2} := flow\_manifold_3$$

$$Q_{nipple} := Q_{bb} + Q_{bb1}$$

$$P_{L8} := \frac{-\left[Q_{bb} - \left[C_{bb}\cdot\left(1.84\cdot10^{-7}\right)\right]\right]}{C_{bb}}$$ $P_{L8} = 1.646\times10^{-7}$

$$P_{bb1} := \frac{Q_{bb1} + con7\cdot P_{L8}}{con7}$$ $P_{bb1} = 1.704\times10^{-7}$

$$P_{nipple} := -\left[\frac{Q_{nipple} - con10\cdot\left(P_{L8}\right)}{con10}\right]$$ $P_{nipple} = 1.291\times10^{-7}$

$$P_{bb2} := \left[\frac{Q_{bb2} + con9\cdot\left(P_{nipple}\right)}{con9}\right]$$ $P_{bb2} = 1.434\times10^{-7}$

$$S_{eff} := \frac{\left(Q_{bb} + Q_{bb1} + Q_{bb2}\right)}{P_{nipple}}$$ $S_{eff} = 180.224$ Required effective pumping speed

From the effective pumping speed, and the equivalent conductance of the D-Plate, the size of the vacuum pump can be determined.

$$size\_of\_required\_vacuum\_pump := \frac{-\left(S_{eff}\cdot con12\right)}{S_{eff} - con12}$$

This is the minimum size vacuum pump that will be required to pump down the D-Plate.

$size\_of\_required\_vacuum\_pump = 242.106$ $\frac{liters}{sec}$

A 300 liter per second pump should be adequate.

We need an effective pumping speed of at least: $Q\_total = 2.357\times10^{-5}$ $\frac{torr\cdot liters}{sec}$

$$Minimum\_Eff\_PS := \frac{Q\_total}{Max\_allow\_pressure}$$ $Max\_allow\_pressure = 1.84\times10^{-7}$ torr

$Minimum\_Eff\_PS = 128.085$ $\frac{liters}{sec}$

This is the pumping speed needed to pump the system down to the required vacuum.

We have a safety factor of:

$$safety\_factor := \frac{S_{eff}}{Minimum\_Eff\_PS}$$

$safety\_factor = 1.407$

This is the safety factor of the system. If it is less than one, the goal isn't met.... i.e., we need a bigger pump.

Therefore, we have sufficient pumping speed to meet the needs of the diagnostic plate.

Calculate approximately how long it take to pump down to the transition region

$$t_{sec} := \frac{Total\_Vol_{cm}}{300} \cdot \ln\left(\frac{760}{3 \cdot 10^{-2}}\right)$$

$$t_{sec} = 3.717 \times 10^{3}$$

$$t_{hours} := \frac{t_{sec}}{3600}$$

$$t_{hours} = 1.033$$